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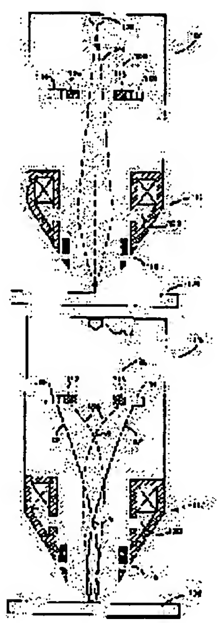
(54) PARTICLE BEAM COLUMN



(57)Abstract:
PROBLEM TO BE SOLVED: To provide a particle beam column for visualizing and measuring the surface shape of a specimen and features of its material with high resolution by installing a detector of an outer circular band of back scattered electrons or secondary electrons that is located in between a particle source and an objet lens and is to detect the inside or the outside circular band of the back scattered electrons, respectively.
SOLUTION: A particle beam PB emitted from a particle source 102 in a particle beam column 100, passing through the center of an electron detector 106 and through an object lens 112 composed of a magnetic object lens 120 and an electrostatic object lens 118, is converged on a specimen 104. The electrons of the primary beam PB allow the surface of the specimen 104 to emit electrons having the kinetic energy of the beam PB varying from as little as zero. The electrons emitted from the specimen 104 are forcused by the object lens 112 and crossed at a secondary electron crossover point A, while back scattered electrons BSE are crossed at a back scattered electron crossover point B; each

of them enters a secondary electron detector 114 or a back scattered electron detector 116, respectively.

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CLAIMS

[Claim(s)]
[Claim 1] It is a particle beam column for imaging and measuring the shape of surface type of a test piece, and the description of an ingredient with high resolution. This particle beam column So that the electron which contains secondary electron and a back scattering electron from a test piece may be made to emit The source of a particle which generates the primary beam which flies in accordance with a primary particle beam shaft, and collides with a test piece, So that the outside annular band which consists of an inside annular band with which the electron which said primary beam shaft was made to distribute an electron to radial [of opposite Perilla frutescens (L.) Britton var. crispa (Thunb.) Decne.], and was distributed consists of a back scattering electron, and secondary electron may be formed The back scattering electron detector which is located between the objective lens which converges said electron, and said source of a particle and said objective lens, and detects the inside annular band of said back scattering electron, The particle beam column characterized by providing the secondary electron detector which is located between said sources of a particle and said objective lenses, and detects the outside annular band of said secondary electron.
[Claim 2] Said objective lens is a particle beam column containing an electrostatic objective lens according to claim 1.
[Claim 3] Said objective lens is a particle beam column containing a magnetic objective lens according to claim 1.
[Claim 4] For said electrostatic lens, said objective lens is a particle beam column according to claim 1 arranged between the test piece and said magnetic objective lens so that the angular position of secondary electron may be maintained including an electrostatic objective lens and a magnetic objective lens.
[Claim 5] Said secondary electron detector and said back scattering electron detector are a

particle beam column according to claim 1 constituted as a single electronic detector.
[Claim 6] Said back scattering electron detector is a particle beam column according to claim 1 which sees from a test piece and is arranged above said secondary electron detector.
[Claim 7] Said back scattering electron detector is a particle beam column according to claim 1 currently formed annularly.
[Claim 8] Said secondary electron detector is a particle beam column according to claim 1 currently divided into two or more sector areas so that two or more signal pairs for measuring the width of face of the line which exists in the front face of said test piece may be supplied.
[Claim 9] Said secondary electron detector is a particle beam column according to claim 8 currently divided into two or more sector areas so that the shape of surface type projected from the test piece and the shape of surface type which are sunken in the test piece may be distinguished.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] Generally especially this invention relates the description of the shape of surface type of a semiconductor wafer,/, and an ingredient to imaging and the electron beam equipment to measure with high resolution by electron beam scan in the automatic process of production of a semi-conductor about particle beam imaging and a measuring device.
[0002]
[Description of the Prior Art] Since a semiconductor integrated circuit is formed in a configuration smaller than the wavelength of a visible ray, M.H.Bennet & G.E. Fuller Paper "In-process Inspection and Metrology of Semiconductor Wafer with the Use of an Automated Low-Voltage SEM, "MicrobeamAnalysis 1986, and pp 649-657 As stated Imaging by the electron beam was established as a technique chosen from a viewpoint of process development and QA.
[0003] If a particle beam collides with a test piece, electron emission will be generated by this test piece. These emission electron is divided roughly into the electron called two kinds of electrons, i.e., the secondary electron the energy of whose is less than 50eV, and the electron called the back scattering electron which is 50eV or more.
[0004] L. Reimer Work "Image Formation in Low-Voltage Scanning Elecron Microscopy", SPIE Optical Engineering Press, and 1993 Secondary electron describes the shape of surface type of a test piece minutely, and another side and a back scattering electron distinguish the dissimilar material contained in a test piece as stated.
[0005] moreover, Halavee etc. -- U.S. Pat. No. 4,941,980 is equipped with four electronic detectors which surrounded the electronic column to which a primary-electron beam is turned to a test piece, and carries out incidence perpendicularly, and have been arranged at equal intervals in the circle configuration, and is indicating the equipment and the approach of measuring the shape of surface type. In order to draw the secondary electron emitted from the test piece, positive charge is impressed to two electronic detectors which counter at coincidence. A test piece is scanned with a primary-electron beam, and the output signal of two detectors with which the charge was impressed is combined so that a test piece surface type-like cross-section configuration may be acquired. In this way, the cross-section configuration which meets the two diagonal lines can be acquired by combining by turns the

output signal of 2 sets of detectors which carried out opposite arrangement. In this conventional example, in order to make easy collection of the secondary electron by the electronic detector arranged around, a comparatively long activity distance called number (several) millimeter at least between the test piece and the electronic column must be maintained.

[0006] Moreover, it adds to the measuring method of the indication to the above-mentioned United States patent. P.Atkin & K.C.A. Paper of Smith "Automatic Stereometry and Special Problems of the SEM", The solid imaging method stated to ElectronMicroscopy and Analysis, Institute of Physics Conference Series Number68, 1983, and pp 219-222 It can use, the output signal of four space detectors can be combined, and indirect three-dimension imaging on the front face of a test piece and measurement are attained.

[0007] U.S. Pat. No. 4,728,790 -- and -- said -- the 4,785,176th A number is indicating electrostatic - MAG objective lens which collects effectively the electrons emitted from a test piece while converging a primary beam on a test piece with high resolution. The scintillator detector arranged above an objective lens generates the signal which is proportional to all electron emission from a test piece. In this conventional example, it has neither of equipment which detects separately the spatial identification unit and secondary electron which used the multiplex detector, and a back scattering electron.

[0008] Moreover, U.S. Pat. No. 4,896,036 is an object detector for scanning electron microscopes (detecfor objective) which consists of an electrostatic objective lens and an annular detector arranged above this objective lens purely. It is indicating. This configuration is usually RAMOA (Larmor) of the electron which happens with a magnetic objective lens. By removing rotation, it has the advantage of saving spatial bearing of a detection electron. However, since there is big chromatic aberration in an electrostatic objective lens as known well, when the energy of a primary beam is low, a limit arises in resolution. This works disadvantageously for application to the semi-conductor which needs low beam energy, in order to avoid the charge and damage on a test piece.

[0009] Therefore, the shape of test piece surface type is identified in very high resolution, and the particle beam column which identifies the description of/or its ingredient is called for.

[0010] So, the purpose of this invention is in offer of the particle beam column which identifies surface type-like discernment and/or the ingredient description of the high resolution of a test piece.

[0011]

[Means for Solving the Problem] This invention is what offers the particle beam column for imaging and measuring the shape of surface type of a test piece, and the description of an ingredient with high resolution. This particle beam column (a) So that the electron which contains secondary electron and a back scattering electron from a test piece may be made to emit The source of a particle which generates the primary particle beam which flies in accordance with a primary particle beam shaft, and collides with a test piece, (b) The objective lens which converges said electron so that the outside annular band which consists of an inside annular band with which the electron which said primary beam shaft was made to distribute an electron to radial [of opposite Perilla frutescens (L.) Britton var. crispa (Thunb.) Decne.], and was distributed consists of a back scattering electron, and secondary electron may be formed, (c) It is located between said sources of a particle and said objective lenses, and it is located between the back scattering electron detector which detects the inside annular band of said back scattering electron, and the source of the (d) aforementioned particle and said objective lens, and the secondary electron detector which detects the outside annular band of said secondary electron is provided.

[0012] According to the 1st gestalt of this invention, the objective lens contains the electrostatic objective lens.

[0013] According to the 2nd gestalt of this invention, the objective lens contains the magnetic

objective lens.
[0014] According to the 3rd gestalt of this invention, said electrostatic lens is arranged between the test piece and said magnetic objective lens so that said objective lens may maintain the angular position of secondary electron including an electrostatic objective lens and a magnetic objective lens.
[0015] According to the 4th gestalt of this invention, said secondary electron detector and said back scattering electron detector are constituted as a single electronic detector.
[0016] According to the 5th gestalt of this invention, said back scattering electron detector is seen from a test piece, and is arranged above said secondary electron detector.
[0017] According to the 6th gestalt of this invention, said back scattering electron detector is formed annularly.
[0018] According to the 7th gestalt of this invention, said secondary electron detector is divided into two or more sector areas so that two or more sets of signals for measuring the width of face of the line which exists in a test piece front face may be supplied.
[0019] According to the 8th gestalt of this invention, said secondary electron detector can distinguish the shape of surface type projected from the test piece, and the shape of surface type which are sunken in the test piece.
[0020] According to the 9th gestalt of this invention, it is the collection detectivity (Acceptance) of the back scattering electron near [said] the primary beam shaft. Potential is given to the operating surface of a back scattering electron detector so that it may be made to improve.
[0021] According to the 10th gestalt of this invention, the above-mentioned basic configuration of this invention consists of an ingredient which raises the collection detectivity of the back scattering electron near [said] the primary beam shaft, and contains further the beam shielded tube equipped with a geometrical flange-like configuration.
[0022]
[Embodiment of the Invention] Many gestalten on the further structure will be understood by these basic configuration of this invention and many gestalten, and the list from the publication of the following related with the suitable example by this invention of the instantiation to an accompanying drawing. However, these examples are given as an example and this invention is not limited to the configuration of these examples.
[0023] This invention images the surface type of a test piece, and the description of an ingredient with high resolution, and relates to the particle beam column which can be measured.
[0024] About the principle of a particle beam column and actuation by this invention, a better understanding can be acquired from an accompanying drawing and the following explanation.
[0025] In order to image and measure the shape of surface type of a test piece, and the description of an ingredient to high resolution, drawing 1 thru/or drawing 3 are constituted based on thinking of this invention, shows suitable 1 example of the particle beam column which operates, and shows the whole by the reference mark 100. Generally, the above-mentioned function of this particle beam column was struck by the primary beam (bombarded). The secondary electron (SE) and back scattering electron (BSE) which are emitted from a test piece It is attained by identifying. Thereby, in this particle beam column, secondary electron can be used for imaging and measuring the test piece surface type-like description to high resolution, and a back scattering electron can be used for imaging and measuring the description of a test piece ingredient to high resolution. Since they distribute to radial in an essentially different radius to the primary beam shaft of a primary beam, secondary electron and a back scattering electron can identify them. ******** -- it originates in the distribution to radial [of secondary electron with a radius and a back scattering electron] having the high energy of a back scattering electron compared with secondary electron.
[0026] The particle beam column 100 has wrapped the source 102 of a particle for scanning

the front face of a test piece 104 by the primary beam PB converged on the precision. suitable -- this source 102 of a particle -- the size of several nanometers parenchyma -- having -- energy spread -- 1(several tenths) eV for dozens of minutes it is -- field emission mold electron source (field-emission electnon source) by which it is thing characterized it is -- a thing is desirable. Typically, a primary beam electron has the kinetic energy exceeding 200eV, and advances in accordance with a primary beam shaft.

[0027] A particle beam PB passes through the core of the electronic detector 106 containing the beam shielded tube 108 equipped with the trailer 110 of a flange mold. In case a primary beam PB passes the electronic detector 106, the above-mentioned shielded tube is formed with the ingredient which is a conductor and is non-magnetic material preferably, and is mostly maintained by this potential with a surrounding column so that a particle beam may not cause a shift or aberration. Activity distance between a test piece 104 and the particle beam column 100 can be shortened very much by arranging the electronic detector 106 inside the particle beam column 100 as known for the technique of this field. In the range which the aberration of a primary beam PB generally increases with activity distance, high resolution and the high accuracy of measurement are attained by taking the above-mentioned configuration.

[0028] The electron of a primary beam makes an electron with the kinetic energy in the range from zero to the kinetic energy of a primary beam PB emit from the front face of a test piece 104. Therefore, the electron emitted from the test piece contains both a back scattering electron and secondary electron. In case a test piece is left, secondary electron is divided into space according to each radiation angle from a different front face so that it may state to a detail with reference to drawing 4 .

[0029] Although the secondary electron emitted from the right-and-left edge section is concentrated on surface type-like left-hand side and right-hand side, respectively when the test piece 104 includes the shape of surface type equipped with the left edge section LE, the flat field FA, and the right edge section RA, as shown in drawing 4 , the secondary electron emitted from the flat field FA separates to spread [both sides] to some extent. The circle which is the pole display of the Lambertain angular distribution well known about secondary electron radiation or cosine-law angular distribution must be noticed about it being shown that secondary electron emission becomes the strongest [in a right-angled direction] on a front face among drawing. Furthermore, it is explained that the direction of the right-and-left edges LE and RE which a primary beam PB foresees to a test piece 104, and carry out incidence close to an angle becomes large rather than it can set to the flat field FA, and the total radiant intensity has a correlation strong between the shape of surface type and secondary electron radiation from this.

[0030] The electron emitted from the test piece 104 converges with the objective lens in which the whole is shown with a reference number 112, and secondary electron is the secondary electron crossover point A. Crossing, a back scattering electron is the back scattering electron crossover point B. It crosses. Since the energy of a back scattering electron is higher than secondary electron, it sees from a test piece 104, as drawing also shows, and it is the cross oboe point B of a back scattering electron. The cross oboe point A of secondary electron It is in a high location substantially. Secondary electron and a back scattering electron face to the electronic detector 106 in accordance with a straight-line orbit within the meridional plane of an objective lens 112 mostly, after passing each cross oboe point.

[0031] Here, the distribution to radial [over the primary beam shaft of the secondary electron in an electronic detector] is large compared with it of a back scattering electron. this -- secondary electron crossover point A from -- the direction of the distance to the electronic detector 106 -- back scattering electron crossover point B from -- it originates in it being larger than the distance to the electronic detector 106. If it puts in another way, electronic radius angular dispersion of waves contains the girdle and the inner girdle of a back scattering

electron outside secondary electron. Therefore, in contrast with the conventional electronic detector, the electronic detector 106 is the secondary electron (SE) detector 114 for detecting a girdle outside secondary electron, and a back scattering electron (BSE) for detecting the inner girdle of a back scattering electron. It has the detector 116. Effective separation of secondary electron and a back scattering electron is a value which shows the outside radius of the back scattering electron detector 116 to drawing 5 . It is attained by choosing so that it may become equal to RO.

[0032] Since an objective lens 112 is described below, it is desirable to be constituted as a compound-die electrostatic-MAG objective lens of a publication by U.S. Pat. No. 4,785,176 possessing the electrostatic objective lens 118 and the magnetic lens 120 which saw from the test piece 104 and was arranged above this electrostatic objective lens 118. It is because it becomes possible to wrest most electronic energy in front of the collision to a test piece 104 so that it can stop the chromatic-aberration effectiveness to the minimum and the electron which collides with another side and a test piece 104 may have the comparatively low landing energy of about 1000eV order, since it becomes usable [the primary particle beam PB of the high energy of about 9000eV order] on the other hand with this kind of objective lens, for example as known for the technique of this field. However, although it becomes resolution lower than the resolution of this compound-die electrostatic-MAG objective lens, constituting an objective lens 112 with an electrostatic objective lens or a magnetic objective lens can want to be careful here.

[0033] First, the electrostatic objective lens 118 of an objective lens 112 turns to the electronic detector 106 the electron emitted from the test piece 104, and accelerates it to several KeV kinetic energy. Subsequently, as for the magnetic objective lens 120 of an objective lens 112, only an include angle theta rotates the electron which passes through this around a primary beam shaft. This include angle theta is given by formula theta=kB / rootU. For a constant and B, at this formula, magnetic field strength and U are [k] RAMOA rotation (Larmorrotation). It is the kinetic energy of the working electron which are known by carrying out.

[0034] The energy spread of secondary electron is about 50eV, and since it is only the pole of all the kinetic energy after the acceleration by the electrostatic objective lens 118 part, it rotates secondary electron at the almost same include angle. If it puts in another way, secondary electron will rotate around a particle beam shaft as if it was the rigid body, and the sequence (topographic ordering) reflecting the shape of surface type which was being maintained when it was in the field of the electrostatic objective lens 118 will be maintained. In contrast with this, since the back scattering electron has different large kinetic energy of breadth, it does not rotate like the rigid body. However, about this point, it does not become particular problem. It is because it is the reinforcement of a backscattering particle rather rather than the angular distribution of a back scattering electron transmits ingredient information.

[0035] In addition, exchange of the location of the electrostatic objective lens 118 and the magnetic objective lens 120 emphasizes what the surface type-like information which secondary electron brings about will be destroyed for. In this case, since those RAMOA rotations differ greatly also between secondary electron only with the difference in several eV energy, include-angle information will get confused completely by spreading through the magnetic objective lens 118.

[0036] As for a secondary electron detector 114 and a backscattering particle detector, being constituted as unified equipment is desirable. In this case, by the approach (explanation is omitted) given in U.S. Pat. No. 4,941,980, a secondary electron detector 114 is divided into four sector areas, as it is shown in drawing 3 , in order to measure the width of face of a line, and as for the back scattering electron detector 116, constituting as an annular ring is desirable. Therefore, the electronic detector 106 supplies five output signals corresponding to

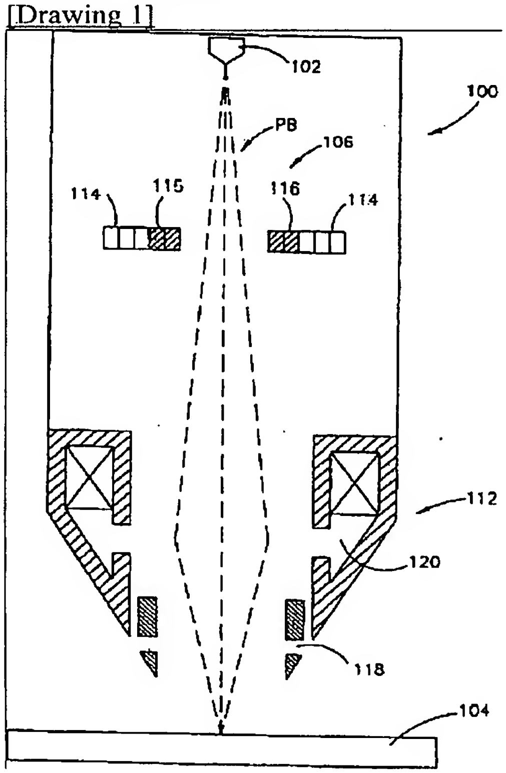
four space secondary electron signals and one back scattering electron signal to a serial or juxtaposition at coincidence. It becomes possible to make the image of one ingredient and one, or the surface type-like image beyond it with all these signals. Or it is also possible to form the surface type-like image of the three dimension which classified superposition and an ingredient presentation for these images by color by the well-known solid image method.
[0037] The number of the sector areas of a secondary electron detector 114 can also be made [also making it fewer than four areas according to whenever / to the direction and spatial discernment ability of the configuration in the field of a test piece 104 / demand /, also making it equal, or / many]. Moreover, it is also possible to dissociate like drawing 6 and to constitute a secondary electron detector 114 and the back scattering electron detector 116. While becoming possible to adjust independently the gain of a secondary electron detector 114 and the backscattering detector 116 according to this design, the advantage of becoming possible to exchange these detectors separately for maintenance is acquired.
[0038] The back scattering electron detector 116 can be easily manufactured by both in secondary electron detector 114 list using the existing techniques, such as a scintillator, a solid state, or a micro-channel-plate electronic detector. The sector area of a secondary electron detector 114 and the annular ring of the backscattering detector 116 can be formed [physical or] by the electronic approach. For example, a micro-channel-plate electronic detector can be manufactured so that it may have the current collection anode plate divided into four sector areas of the illustration to drawing 3 , and two or more physical fields of the configuration corresponding to one annular ring.
[0039] The micro-channel-plate electronic detector known well consists of 1, or two or more thin glass plates and current collection anode plates (collecting anode), and many microtubules are formed in the direction perpendicular to the field of a glass plate at this glass plate. And between two front faces of this glass plate, the electrical potential difference of about 1000 V is impressed. An electron goes into the so-called "input flat surface", and is accelerated in the direction of an "output front face" with applied voltage. In the meantime, whenever an electron is rebounded by the inside of the above-mentioned microtubule and it is rebounded once, some electrons are emitted from glass. Since electron emission ability is increased, this glass often contains lead. By rebounding an electron repeatedly by the inside of the above-mentioned microtubule, one electron which carried out incidence to the input front face has generated thousands of electrons, when arriving at an output front face. A current collection anode plate consists of insulators which were located in parallel with the above-mentioned output front face, and were insulated from the output front face, and has two or more metallic-coating fields on the front face of the insulator. A current collection anode plate is maintained by the potential of 1050V, and is held from an output front face at the distance of 1/several millimeters. Thousands of above-mentioned electrons pass through the output front face of the above-mentioned glass plate, and arrive at a current collection anode plate. In this way, a measurable current occurs. Two or more above-mentioned metallic-coating fields serve as an insulated electrode. Such a micro-channel-plate electronic detector of a configuration is more nearly available than for example, Hamamatsu Photonics, Inc. And it is possible to manufacture the electrode of these plurality in a configuration like the illustration to drawing 3 .
[0040] being certain -- it is -- moreover, it is also possible to use the micro-channel-plate electronic detector which measures electronically the location of each electron which strikes a detector front face and in which location detection is possible. An analog or a digital accumulator is used for electronic collision frequency, and it counts it for every annular ring of each sector area of a secondary electron detector 114, and a back scattering electron detector.
[0041] Furthermore, the sector area of a secondary electron detector 114 and the annular ring of the backscattering detector 116 are Everhart-Thornley. It is possible to create as discrete-

type equipment like the scintillator electronic detector of a mold. carry out for constituting physically -- moreover, carry out for constituting electronically -- there is no change in the principle of include-angle distinction of secondary electron, and the principle about separation to radial [of secondary electron and a back scattering electron].
[0042] In case the pars-basilaris-ossis-occipitalis surface structure called the slot and contact hole of a semiconductor wafer is imaged and measured, the detectivity of the back scattering electron near the shaft improves in a desirable form by applying the technique of a publication to U.S. Pat. No. 5,466,940. This is attained by giving potential to the field (active surface) of operation and the flange edge 110 of a back scattering electron detector so that these secondary electron may be collected effectively, as stated to U.S. Pat. No. 5,466,940, while forming the flange edge 110 with the ingredient which makes easy generating of the secondary electron by the back scattering electron which collides.
[0043] As mentioned above, although a number of examples to which this invention was restricted have been explained, it will be understood by this invention that much deformation and other application are possible.
[0044]
[Effect of the Invention] According to this invention, the shape of surface type and the ingredient description of a test piece are discriminable with high resolution.

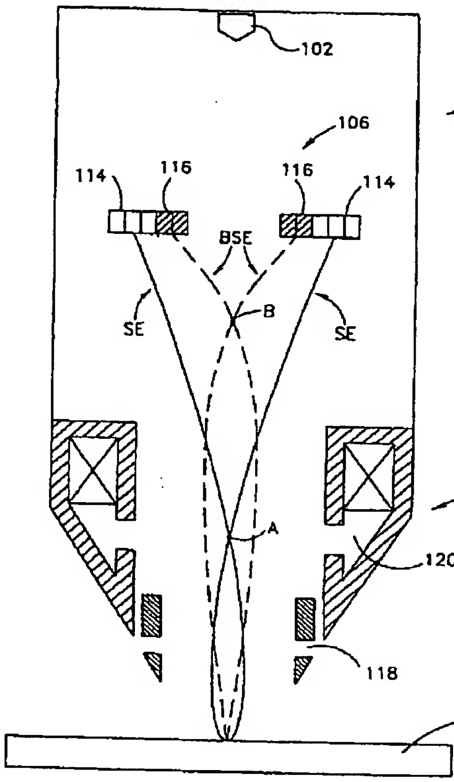
[Translation done.]

DRAWINGS

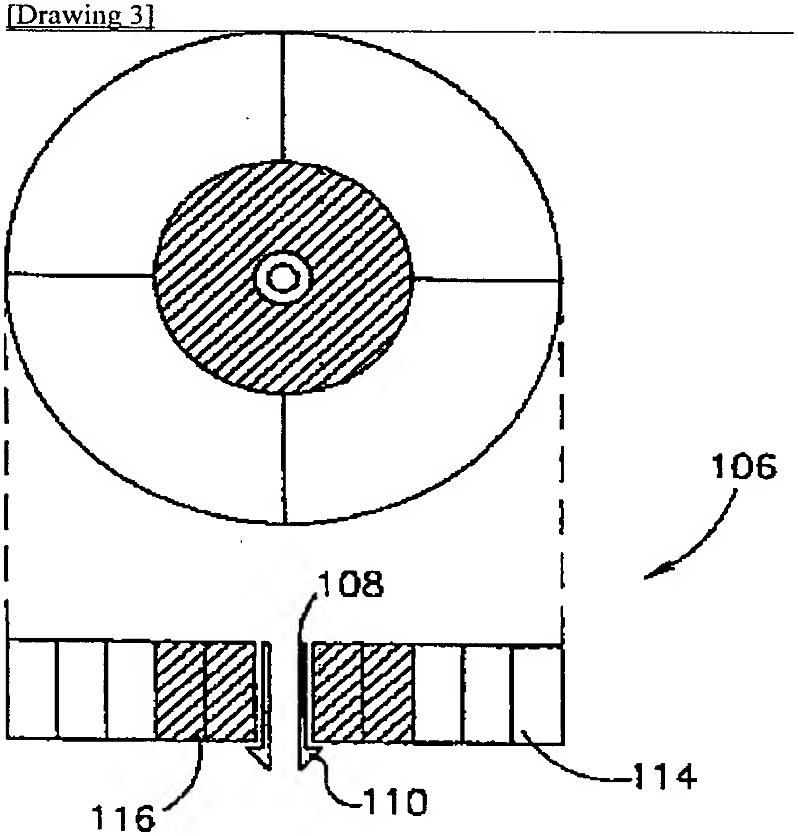
[Drawing 1]



[Drawing 2]


102
100
106
114
116
116
114
BSE
SE
B
SE
112
A
120
118
104

[Drawing 3]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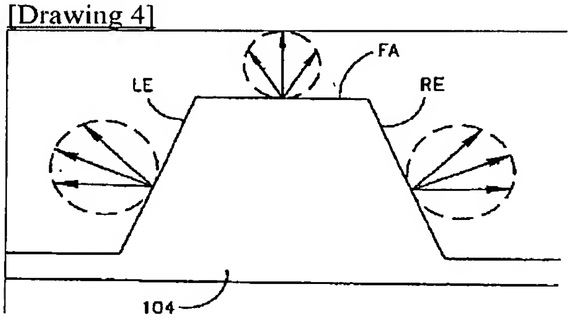
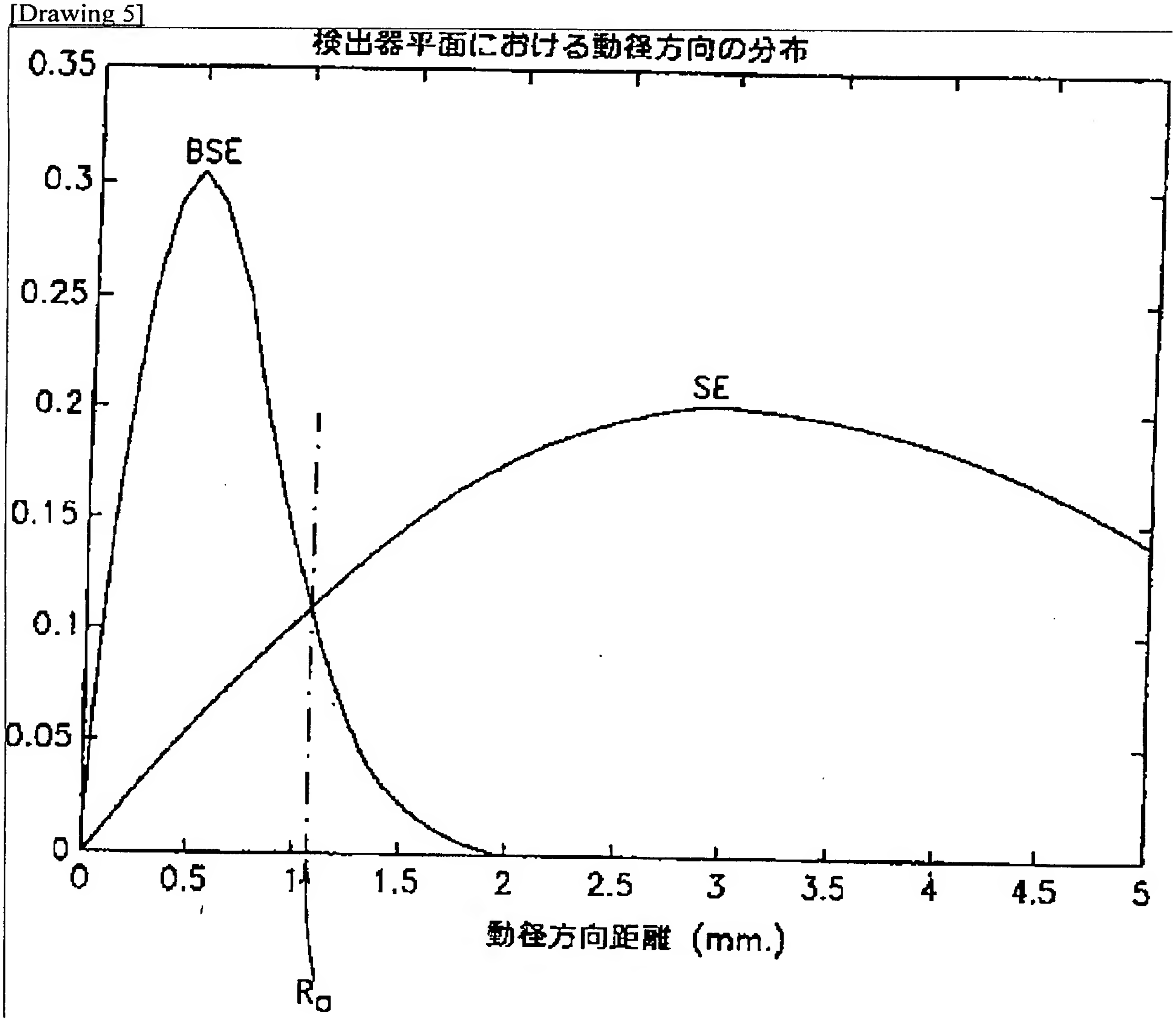
108
116
110
114

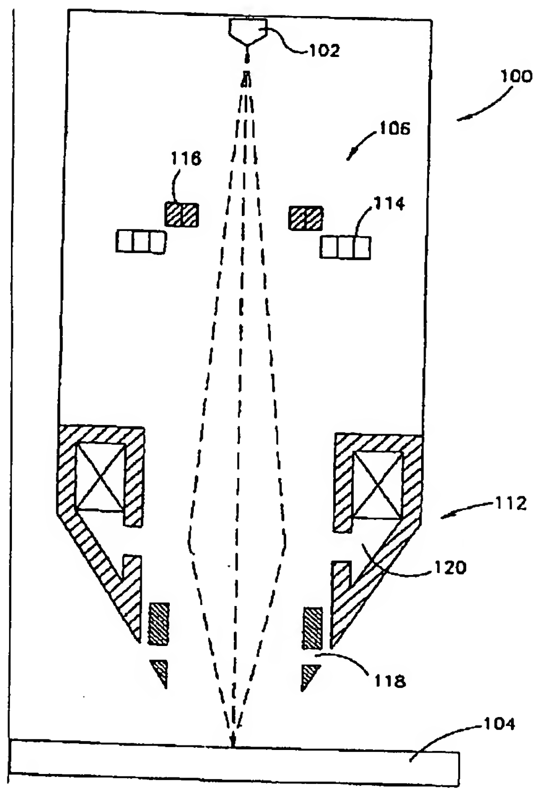
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]